Short-Crested Breaking Waves and Vorticity

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LONG-TERM GOALS

The long-term goal is to determine the contribution of short-crested breaking waves to vorticity (and thus mixing) in nearshore regions and near strong flows from inlets or river mouths.

OBJECTIVES

The objectives of our research in FY13 were:

- Preparation and revision of a manuscript on vorticity generated by short-crested breaking waves
- To investigate the relationship between vorticity generation and the low frequency eddies that drive surfzone tracer dispersion
- Determine the usefulness of high-resolution ultra wide-angle optical images for measuring breaking wave crest lengths

APPROACH

Our approach is to develop new field methods and instrumentation to enable measurements of the processes affecting vorticity, and to assess the importance of those physical processes to numerical models of the nearshore region.

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WORK COMPLETED

We finished the revision and publication of an article titled "Vorticity generation by short-crested breaking waves." The article was published in Geophysical Research Letters, and featured on the December 2012 cover (Figure 1). The data from the 2011 VORTEX pilot study was further analyzed for connections between vorticity generated by short-crested breaking waves and the low frequency horizontal eddies thought to mediate tracer dispersion.

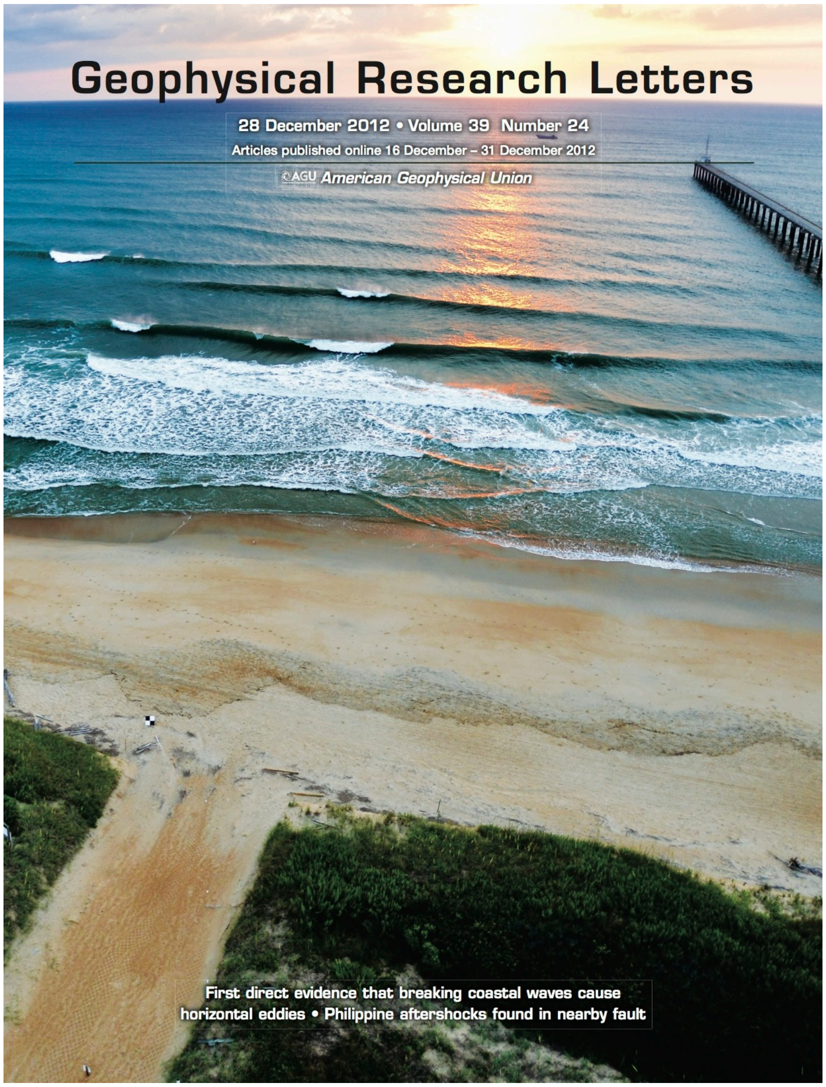

Figure 1. The cover of Geophysical Research Letters featuring short crested waves breaking at Duck, NC. This image is a small subsection of a high-resolution ultra-wide angle image considered for remote sensing of breaking wave crests.

The initial analysis was completed on high-resolution ultra-wide angle optical images of the surfzone acquired in July 2012. The images were compared with existing beach imagery (e.g., ARGUS) for the potential to identify individual breaking wave faces in the surfzone and to measure the lengths of breaking crests (thought to control wave generated vertical vorticity).

RESULTS

Low frequency eddies are thought to be the primary process that disperses tracers in the surfzone and nearshore, but the mechanisms that generate these eddies are not understood. We found that the strength of low frequency eddies was highly correlated with the magnitude of vorticity generated by short crested breaking waves, which varied over a tidal cycle (Figure 2). The high correlation suggests that short-crested breaking waves are a significant control on nearshore tracer dispersion, and the effects of short-crested breaking should be included in wave averaged models when accurate eddy diffusivity or tracer dispersion estimates are required.

High-resolution ultra wide-angle optical images were explored as a method for remote sensing of individual breaking wave crests. The ultra wide-angle images spanning > 500 m of shoreline captured the entire length of breaking crests for waves with moderate directional spreads ($\sigma_\theta \sim 20^o$). Unlike stitched images from multiple cameras (e.g., ARUGS) the ultra-wide angle images do not suffer from time sync and rectification artifacts at the stitch edges. Stitching artifacts cause discontinuities in the image of a breaking crest and impair crest length measurements. High resolution images may make it possible to identify the turbulent front faces of breaking waves by resolving the high wavenumber variations in pixel intensity found in those regions.

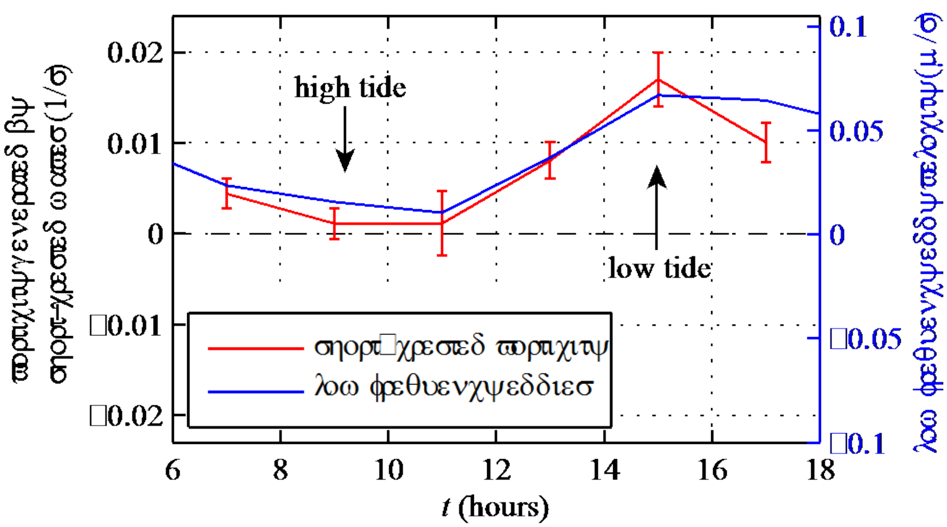

Figure 2. Vorticity generated by individual short-crested breaking waves within the surfzone (red curve), shown as 2-hour binned means ± the error in the mean, and the rms low frequency eddy velocity (blue curve) versus time t. The generated vorticity varies with the tidal water depth, with low vorticity at high tide (near t = 9 hours) and high vorticity at low tide (near t = 15 hours). The strength of low frequency eddies is highly correlated with the magnitude of wave generated vorticity (r = 0.94), and suggests that short-crested breaking waves are a primary forcing mechanism for surfzone eddies and tracer dispersion. The transfer of energy from small scale O(10 m) eddies generated by breaking waves to low-frequency large-scale O(100 m) eddies is expected for the quasi 2D flows found at those scales in the surfzone.

IMPACT/APPLICATIONS

This project made the first measurements of surfzone vorticity about a vertical axis (i.e., horizontal eddies), and the first measurements of vertical voritcity generated by short crested breaking waves. Short-crested breaking is found to be a significant source of surfzone vorticity, and high correlations with low frequency eddies suggest short-crested breaking is a controlling factor on surfzone tracer dispersion. Our study indicates that the effects of short crested breaking waves should be included in numerical models of the surfzone.

High-resolution ultra wide-angle images of the surfzone are a promising tool for measuring breaking crest-length and other parameters that could determine the influence of short-crested breaking on surfzone flows. The image processing required for this analysis is complex and beyond the scope of this project, however we plan to continue exploring image-processing solutions in the future. An image processing planning letter was submitted in April 2013 to the ONR Littoral Geosciences & Optics Program for CORE funding, with extensions to identifying active wave breaking with radar.

RELATED PROJECTS

An ongoing surfzone vorticity project funded by NSF complements the pilot project analysis funded by this ONR project. A month-long time series of surfzone vorticity will be used to explore the variation in wave-generated vorticity over a range of wave conditions.

PUBLICATIONS

Clark, D.B., S. Elgar, and B. Raubenheimer (2012), (COVER) Vorticity generation by short-crested breaking waves, *Geophysical Research Letters,* 39, L24604, doi:10.1029/2012GL054034, [published, refereed]

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